## iii. Refrigerator Cycle Calculations

The process requirements for the RHIC helium refrigerator to meet the baseline heat load are presented here. Other cases with higher loads have been studied, and the results may be found in Tech Note AD/RHIC/RD-74, along with details of this calculation. The compressor flow required for the refrigerator to meet the baseline load is approximately 60% of the installed compressor capacity. The reference schematic for these calculations is shown in Fig. 3-3. The calculated process state points for this case are given in Tables 3-7A and 3-7B. As shown in Table 3-7B, the calculated electric power required for the main compressors to satisfy this operating point is 8.8 MW.

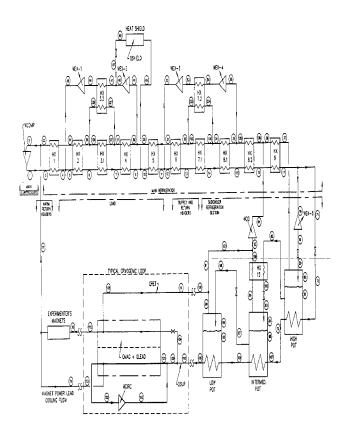


Fig. 3-3. RHIC refrigerator schematic.

Table 3-7A. Process Requirement for RHIC Refrigerator at Design Heat Load

 $\label{eq:Fluid Properties and Flow Rates}$  Pressure (bar), Temperature (K), Enthalpy (J/g) and Flow Rate (g/s)

4 1 6 1 11	17.25 16.28 16.18 15.64 15.64 15.56 12.50 1.42 1.35 1.35 1.35 1.35 1.35 1.35 1.35	305.00 180.00 151.78 40.00 25.00 20.73 8.13 5.02 4.98 4.62 4.56 4.13 4.14 4.14 4.22 4.20 302.01 172.02	1604.33 954.62 807.86 222.00 139.41 114.75 32.79 18.88 14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	2486.45 2486.45 1853.27 1853.27 1448.95 647.81 647.81 259.04 33.40 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	3 5 7 10 12 14 18 20 81 182 84 86 87 99 92 94 23 24	16.40 16.28 16.00 15.67 15.57 15.54 15.49 1.42 1.41 1.35 1.35 1.35 .93 .92 1.40	305.00 180.00 65.84 40.00 25.00 12.45 5.44 5.03 4.63 4.63 4.56 4.56 4.56 4.14 4.21 5.24	1604.04 954.62 359.22 222.00 139.41 63.23 20.37 18.88 14.31 12.06 29.68 29.68 29.68 30.15 30.15 30.84 35.62	2486.45 1853.27 1853.27 1448.95 647.81 647.81 259.04 259.04 21.66 23.48 47.80 343.56 343.56 343.56 343.56
6 1 9 11 113 1 115 1 17 1 19 80 823 85 888 8991 24 1 226 226 230 334 234 35 136 37 46 48 52 1	16.18 15.664 15.656 15.550 1.425 1.355 2.355 2.993 2.993 2.995 1.17	151.78 40.00 25.00 20.73 8.13 5.02 4.62 4.62 4.56 4.13 4.14 4.12 4.20 302.01 172.02	807.86 222.00 139.41 114.75 18.88 14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	1853.27 1853.27 1448.95 647.81 647.81 259.04 33.40 71.28 69.61 23.48 47.80 42.49 343.56 367.04	7 10 12 14 15 18 20 81 182 84 86 87 89 99 92 94	16.00 15.67 15.64 15.57 15.54 1.42 1.42 1.41 1.35 1.35 1.35 .93 .92 1.40	65.84 40.00 12.45 5.44 5.03 4.62 4.61 4.56 4.56 4.14 4.14 4.14 5.24	359.22 222.00 139.41 63.23 20.37 18.88 14.31 12.06 12.06 29.68 11.64 30.15 30.15 30.84	1853.27 1448.95 647.81 647.81 259.04 225.64 71.28 1.67 23.48 47.80 343.56
6 1 9 11 113 1 115 1 17 1 19 80 823 85 888 8991 24 1 226 226 230 334 234 35 136 37 46 48 52 1	16.18 15.664 15.656 15.550 1.425 1.355 2.355 2.993 2.993 2.995 1.17	151.78 40.00 25.00 20.73 8.13 5.02 4.62 4.62 4.56 4.13 4.14 4.12 4.20 302.01 172.02	222.00 139.41 114.75 32.79 18.88 14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.77 1583.34 908.29	1853.27 1448.95 647.81 647.81 259.04 33.40 71.28 71.28 69.61 23.48 47.80 42.49 343.56 367.04	10 12 14 15 18 20 81 182 84 86 87 89 99 92	15.67 15.64 15.57 15.49 1.42 1.41 1.35 1.35 .93 .92 1.40	40.00 25.00 12.45 5.44 5.63 4.62 4.61 4.56 4.56 4.14 4.14	222.00 139.41 63.23 20.37 18.88 14.31 12.06 29.68 11.64 30.15 30.15 30.88	1448.95 647.81 647.81 259.04 259.04 225.64 71.28 47.80 5.31 47.80 343.56
9 1 11 13 1 115 1 17 19 80 82 83 85 186 88 90 91 224 1226 227 30 31 31 44 32 35 136 37 46 48 52 1	15.68 115.64 115.56 12.50 1.42 11.43 1.35 1.35 1.93 1.93 1.91 1.17	40.00 25.00 20.73 8.13 5.02 4.98 4.62 4.56 4.13 4.14 4.22 4.20 302.01 172.02	222.00 139.41 114.75 32.79 18.88 14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.77 1583.34 908.29	1448.95 647.81 647.81 259.04 33.40 71.28 69.61 23.48 47.80 42.49 343.56 367.04	12 14 15 18 20 81 182 84 86 87 89 99 92 94	15.64 15.57 15.54 15.49 1.43 1.41 1.35 1.35 .93 .92 1.40	25.00 12.44 5.03 4.62 4.61 4.56 4.56 4.14 4.14 5.24	139.41 63.23 20.37 18.88 14.31 12.06 12.06 29.68 11.64 30.15 30.15 30.15	647.81 647.81 259.04 259.04 225.64 71.28 47.80 47.80 3467.04
13 1 115 1 17 1 19 80 82 83 186 85 186 890 91 24 126 227 30 33 134 235 136 48 48 52 1	15.61 15.56 15.56 2.50 1.42 1.35 2.93 .93 .93 .93 .93 .95 1.17	20.73 8.13 5.02 4.98 4.62 4.56 4.13 4.14 4.12 4.20 302.01 172.02	114.75 32.79 18.88 14.31 12.06 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34	647.81 647.81 259.04 33.40 71.28 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	14 15 18 20 81 182 86 87 89 99 92 94	15.57 15.54 15.49 1.43 1.42 1.35 1.35 1.35 1.35 1.35	12.45 5.44 5.03 4.63 4.61 4.56 4.14 4.14 4.21	63.23 20.37 18.88 14.31 12.06 12.06 29.68 11.64 30.15 30.15 30.84	647.83 647.83 259.04 225.64 71.26 23.48 47.80 347.80 3467.04
115 1 19 80 82 83 885 1866 890 911 2266 2267 303 1344 2345 336 3468 488 3468 3518 367468 3688 3788 3788 3788 3788 3788 3788 37	15.56 15.53 2.542 1.42 1.35 1.35 .93 .93 .92 1.05 1.17	8.13 5.02 4.98 4.62 4.56 4.13 4.14 4.22 4.20 302.01 172.02	32.79 18.88 14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	647.81 647.81 259.04 33.40 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	15 18 20 81 182 86 87 89 92 92	15.54 15.49 1.43 1.42 1.41 1.35 1.35 1.35 1.35 1.35	5.44 5.03 4.62 4.61 4.56 4.56 4.14 4.12 5.24	20.37 18.88 14.31 12.06 12.06 29.68 29.68 11.64 30.15 30.15	647.81 259.04 259.64 71.28 1.61 23.48 47.80 5.31 47.80 343.56
17 1 19 80 823 85 1886 991 224 1226 27 334 234 51234 5134 448 852 1	15.53 2.50 1.42 1.35 1.35 .92 .93 .92 .92 1.05 1.17	5.02 4.98 4.62 4.56 4.56 4.13 4.14 4.22 302.01 172.02	18.88 14.31 29.51 12.06 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34	647.81 259.04 33.40 71.28 69.61 23.48 47.80 42.49 343.56 367.04	18 20 81 182 84 86 87 89 99 92 94	15.49 1.43 1.42 1.41 1.35 1.35 1.35 .93 .93 .92 1.40 1.10	5.03 4.63 4.62 4.56 4.56 4.14 4.14 4.21 5.24	18.88 14.36 12.06 12.06 29.68 11.64 30.15 30.15	259.04 259.04 225.64 71.28 1.67 23.48 47.80 343.56 343.56
19 80 83 83 85 186 88 90 91 221 226 30 31 34 42 35 136 48 48 48	2.50 1.42 1.35 1.35 .92 .93 .92 .92 1.05 1.17	4.98 4.62 4.56 4.56 4.13 4.14 4.22 4.20 302.01 172.02	14.31 29.51 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	259.04 33.40 71.28 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	20 81 182 84 86 87 89 99 92 94 23	1.43 1.42 1.41 1.35 1.35 1.35 .93 .93 .92 1.40	4.63 4.62 4.61 4.56 4.56 4.14 4.14 5.24	14.31 12.06 12.06 29.68 29.68 11.64 30.15 30.15	259.04 225.64 71.28 1.67 23.48 47.80 5.31 47.80 343.56 3467.04
80 82 83 85 88 91 921 24 226 226 233 33 34 234 35 136 48 88	1.42 1.42 1.35 1.35 .92 .93 .93 .92 .92 1.05 1.14	4.62 4.62 4.56 4.56 4.13 4.14 4.22 302.01 172.02	29.51 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34	33.40 71.28 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	81 182 84 87 89 99 92 94	1.42 1.41 1.35 1.35 1.35 .93 .93 .92 1.40	4.62 4.61 4.56 4.56 4.14 4.14 4.21 5.24	12.06 12.06 29.68 29.68 11.64 30.15 30.15 30.84 35.62	225.64 71.28 1.67 23.48 47.80 5.31 47.80 343.56 367.04
82 83 85 186 890 91 21 224 126 227 30 33 134 235 136 48 48	1.42 1.35 1.35 .92 .93 .93 .92 1.05 1.14 1.17	4.62 4.56 4.56 4.13 4.14 4.22 4.20 302.01 172.02 149.88	12.06 12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	71.28 71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	182 84 86 87 89 99 92 94	1.41 1.35 1.35 1.35 .93 .93 .92 1.40	4.61 4.56 4.56 4.14 4.14 4.21 5.24	12.06 29.68 29.68 11.64 30.15 30.15 30.84	71.28 1.67 23.48 47.80 5.31 47.80 343.56
83 186 88 90 91 21 226 226 30 33 134 435 136 48 48	1.35 1.35 .92 .93 .93 .92 .92 1.05 1.14 1.17	4.56 4.56 4.13 4.14 4.24 4.20 302.01 172.02 149.88	12.06 11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	71.28 69.61 23.48 47.80 42.49 343.56 367.04 2486.45	84 86 87 89 99 92 94	1.35 1.35 1.35 .93 .93 .92 1.40	4.56 4.56 4.56 4.14 4.11 5.24	29.68 29.68 11.64 30.15 30.15 30.84 35.62	1.67 23.48 47.80 5.31 47.80 343.56 367.04
85 186 88 90 91 93 21 24 126 227 33 33 134 235 136 48 48	1.35 .92 .93 .93 .92 .92 1.05 1.14	4.56 4.13 4.14 4.22 4.20 302.01 172.02 149.88	11.64 29.68 11.64 9.32 30.84 30.77 1583.34 908.29	69.61 23.48 47.80 42.49 343.56 367.04 2486.45	86 87 89 99 92 94 23	1.35 1.35 .93 .93 .92 1.40	4.56 4.56 4.14 4.14 4.21 5.24	29.68 11.64 30.15 30.15 30.84 35.62	23.48 47.80 5.31 47.80 343.56 367.04
186 890 913 221 1226 303 134 1235 1335 1336 4482	.92 .93 .93 .92 .92 1.05 1.14	4.13 4.14 4.14 4.22 4.20 302.01 172.02 149.88	29.68 11.64 9.32 30.84 30.77 1583.34 908.29	23.48 47.80 42.49 343.56 367.04 2486.45	87 89 99 92 94 23	1.35 .93 .93 .92 1.40 1.10	4.56 4.14 4.14 4.21 5.24	11.64 30.15 30.15 30.84 35.62	47.80 5.31 47.80 343.56 367.04
88 991 931 224 1226 227 334 2334 2335 1337 468 482	.93 .93 .92 .92 1.05 1.14	4.14 4.14 4.22 4.20 302.01 172.02 149.88	11.64 9.32 30.84 30.77 1583.34 908.29	47.80 42.49 343.56 367.04 2486.45	89 99 92 94 23	.93 .93 .92 1.40 1.10	4.14 4.14 4.21 5.24	30.15 30.15 30.84 35.62	5.31 47.80 343.56 367.04
90 91 21 126 226 230 33 134 234 235 137 46 48 52	.93 .92 .92 1.05 1.14 1.17	4.14 4.22 4.20 302.01 172.02 149.88	9.32 30.84 30.77 1583.34 908.29	42.49 343.56 367.04 2486.45	99 92 94 23	.93 .92 1.40 1.10	4.14 4.21 5.24	30.15 30.84 35.62	47.80 343.56 367.04
91 93 21 24 126 227 30 134 234 35 136 37 46 48 52	.92 .92 1.05 1.14 1.17	4.22 4.20 302.01 172.02 149.88	30.84 30.77 1583.34 908.29	343.56 367.04 2486.45	92 94 23	.92 1.40 1.10	4.21 5.24	30.84 35.62	343.56 367.04
93 224 1226 227 3334 235 1337 468 482 1	.92 1.05 1.14 1.17	4.20 302.01 172.02 149.88	30.77 1583.34 908.29	367.04 2486.45	94 23	1.40	5.24	35.62	367.04
21 24 126 226 27 33 134 234 35 136 37 46 48 52	1.05 1.14 1.17	302.01 172.02 149.88	1583.34 908.29	2486.45	23	1.10			
24 126 227 30 33 134 35 136 37 46 48 52	1.14	172.02 149.88	908.29				302.00	1587 74	
126 226 27 30 33 134 234 35 136 37 46 48 52	1.17	149.88		2393.45	26				
226 27 33 134 234 35 136 37 46 48 52	1.17					1.17	149.88	793.30	2393.45
27 30 33 134 234 35 136 37 46 48 52 1			793.30	1783.57	127	1.24	60.00	326.38	1783.57
30 33 134 234 35 136 37 46 48 52 1	1.17	149.88	793.30	609.88	227	1.24	60.00	326.38	609.88
33 134 234 35 136 37 46 48 52 1	1.24	60.00	326.38	2393.45	29	1.29	39.42	219.34	2393.45
134 234 35 136 37 46 48 52 1	1.31	39.42	219.34	1355.95	31	1.32	22.50	130.91	1355.95
234 35 136 37 46 48 52 1	1.33	20.13	118.44	1355.95	133	1.33	20.13	118.44	626.21
35 136 37 46 48 52 1	1.35	10.06	64.67	626.21	233	1.33	20.13	118.44	729.75
136 37 46 48 52 1	1.35	10.06	64.67	729.75	34	1.35	10.06	64.67	1355.95
37 46 48 52 1	1.39	7.50	50.13	1355.95	135	1.39	7.50	50.13	554.81
46 48 52 1	1.40	5.24	35.62	554.81	36	1.40	5.24	35.62	187.77
48 52 1	1.41	4.62	29.51	187.77	45	16.23	180.00	954.62	633.18
52 1	9.00	151.78	805.66	633.18	47	8.90	65.84	358.03	633.18
	8.86	65.84	358.03	1037.49	49	1.30	39.42 20.73	219.34 118.09	1037.49
	15.58	25.00	139.41	801.15	53	8.00			
	7.92	12.45	69.49	801.15	55	1.41	7.50	50.13 358.03	801.15
	8.90	65.84	358.03	404.32	68	9.67	65.81	18.88	404.32
	15.67	40.00	222.00	404.32	71	15.49 5.03	5.03 4.67	12.82	388.77
72	5.13	5.76	18.88	388.77	73			11.02	388.77
	4.58	4.50	11.94	48.00 93.00	76	.98 5.00	4.20 6.56	27.69	45.00 24.00
77	1.07	302.00	1583.33 15.50	124.00	100 102	4.58	4.50	11.94	100.00
	5.00	5.21	12.57	100.00	102	5.01	4.19	11.02	170.38
103	5.00 .98	4.62	30.14	147.88	104	.93	4.19	30.95	295.77
105		4.20 4.67	12.82		108	5.02	4.23	12.55	388.77
107	5.03 5.01	4.19	12.82	388.77 388.77	110	5.02	4.19	11.02	194.38
109			30.95	147.88	110	.98	4.19	11.02	22.50
111 113	.93	4.23 4.50	11.94	24.00	112	.90	4.20	11.02	22.50

						PRO	MARDO	RHIC						
Calcul Vacuu	late pe m compi	rforman ressor.	ce of circu	alatis	ag com	02000	sore 1	tor wh ocated ugh the	in th	me rich	= 5 e	e use	ders an	nd 1 col irculate
					SUMMAR	Y OF	SYSTE	M PARAL	ETER:					
Refrigeratio			on (₩)						ow (g/≡)					
QMAG 2875.	QLEAD 1855.		240.	55.	368.					F74 48.		176 45.		
			ESTIM					IN HEAT						
950.	HX2 3240.	8X3 2670.	HX4 1880.	240		۰.	600.	920.	HX	S. H.	O.	290	POT	L POT
								PARAME						
Heat Exchar	nger	Flow 9/s	IF*	0w P 10w /s		MIN /		ffectivess Rat		AU Req	uired N	iro		esign U W/K
1.0 2.0 3.1 3.0 4.0 6.0		2486.4 1853.3 1853.3 633.2 18449.0 647.8	21	393.4 393.4 789.9 396.0 356.0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	.040 .276 .046 .226 .1296	Ē	977 937 979 979 978 967 944		317.0 64.2 240.6 814.3 94.9 126.6	221	5.56 5.66 5.66 5.40 3.43 7.96	1: 5: 2: 2:	84.0 83.1 33.8 03.8 01.2 53.4
7 - 1 7 - 2 8 - 2 9 - 0		647.8 801.1 647.8 647.8	1	729.7 356.0 554.8	1 1 1	. 216 . 689 . 191 . 484	=	944 895 947 807		31.0 13.9 14.0 3.1		7.95 3.05 4.68 1.69	1	48.5 33.7 61.8 11.5
							ER PAI	CAMETER	314					
Turbir	ne	P <sub>IN</sub> Dar	P lo	OUT A.F	K			K		5/5W		ETA		WOEK W
1.0 2.0 3.0 4.0 5.0		16.23 8.86 15.58 7.92 15.49	8	.00 .30 .41 .50		80.00 55.84 25.00 12.45	<u>.</u>	151.78 39.42 20.73 7.50 4.98		633. 1037. 801. 801. 259.		- 75 - 75 - 70 - 70 - 50	3	94317. 43895. 17080. 15512.
					COM	CPRES	SOR PA	RAMETE	RS					
Comp.	Iso- ther. mff.	Adia- batic Eff.	P <sub>IN</sub>	Pour bar	T114	7	our	Flow g/s	Work kW	. Wos		IN VO1 F1 ACFM	IN Densi g/cm <sup>2</sup>	Pres Ratio
Main Cold Circu One c	.50 irculat	.60 .50 .ing dom	1.05 .92 4.58 presso	17.2 1.40 5.00	4.2	0 4	05.0 1.24 1.62	2486. 367.0 100.0	8803 1.77 .063	9 2.5	BO1. 385 34	52.4 cops	:0148 :136	1.531
						LO	AD SUM	MARY						
			Suppl	imary Y	Load Return	•			84	Second pply	Re Re	Load sturn		
Temper	Rate (g ura (ba ratura lpy (J/	.E) (医)	388.77 5.01 4.19 11.02	•	295.77 .93 4.23 30.95				4	4.32 5.67 0.00 2.00	6	4.32 9.67 5.81 8.03		